REMARKS

Upon entry of the Amendment, Claims 1-170 will be pending in the application. Claims 57-157 are withdrawn from consideration by the Examiner.

Claims 1-4 and 158 are amended to clarify that the second metal is different from a metal in the adjoining under-bump layer, wherein the intermetallic compound is formed between the solder bump and the adjoining under-bump layer. Support can be found, for example, in Fig. 1. Claims 1-4 are also amended to replace "formed on" with "formed above" for clarification. No new matter is added.

New Claims 163-170 are added. Applicants submit that no new matter is added.

Entry of the Amendment along with reconsideration and review of the claims on the merits are respectfully requested.

Formal Matters

Applicants appreciate entry of the RCE filed on June 22, 2004, and entry of the Amendment under 37 CFR 1.116 filed on May 12, 2004.

Applicants also appreciate that the Examiner has considered and returned an initialed copy of the Information Disclosure Statement filed on March 22, 2004.

Claim Rejections - 35 USC § 103

A. Claims 1, 3, 5, 7, 9, 11, 21, 22, 25, 26, 29-33, 39-43, 158, 159 and 161 are rejected under 35 U.S.C. §103(a) as assertedly being unpatentable over Marlin (US Patent

6,429,046) in view of Chan et al (US Patent 5,471,092) for the reasons given in the Office Action.

Regarding claims 1, 3 and 158, the Examiner recognizes that Marlin fails to teach an intermetallic compound being formed between the solder bump and the UBL, the intermetallic compound including a metal that is a main component of the alloy solder and a second metal different from that of the metal of the main component and that of the UBL. However, the Examiner asserts that Chan et al teaches a solder ball/UBL reflow structure where an intermetallic compound including metals such as tin (Sn) and copper (Cu) is formed after solder reflow of tin based alloy solder having tin as a main component on a metal/solder reactive layer comprising copper to prevent formation of the intermetallics in the underlying layers, improve adhesion and to reduce the joint stress, the intermetallic compound/Cu-Sn including the main component/metal (Sn) of the alloy solder and the second metal such as Cu, which is different than the main component of the alloy solder and also being different from the metal of the UBL such as Ti or W (Chan, cols. 3-6). (see Office Action, page 4, first full paragraph).

B. Claims 2, 4, 6, 8, 10, 12, 23, 24, 27, 28, 34-38, 44-48, 55, 56, 160 and 162 are rejected under 35 U.S.C. §103(a) as assertedly being unpatentable over Marlin in view of Chan et al and Darveaux et al (US Pat. 6,201,305) for the reasons given in the Office Action.

Regarding independent claims 2 and 4, the Examiner asserts that Darveaux et al makes up for the deficiencies in Marlin and Chan by teaching a solder ball mounting structure having

underbump layer such as nickel on a laminated pad where an intermetallic compound such as tin-nickel (SnNi) is formed, the intermetallic compound including the metal/first metal such as nickel and the main component of the alloy of the solder ball such as tin.

In response to Applicants' previous arguments, the Examiner emphasizes that, as shown in the final structure in Marlin (see Fig. 6), the solder bump comprises elements including tin and copper (see 310/308 in Fig. 6; col. 2, lines 19 and 60) and the UBL comprising Ti or TiW (element 302 in Fig. 6). The Examiner cites Chan et al. as teaching the intermetallic compound including Sn and Cu being formed after solder reflow of tin based alloy solder (col. 3, lines 20-56). Such intermetallic compound/Cu-Sn includes the main component/Sn of the alloy solder and the second metal such as Cu, which is different than the main component of the alloy solder and also being different from the metal of the UBL such as Ti or W.

Applicants respond as follows.

Applicants submit that the combination of Marlin with Chan, and further in view of Darveaux, does not disclose, teach or suggest each and every requirement of Applicants' claims. Applicants incorporate the entire remarks previously submitted in the Amendment filed May 12, 2004, portions of which are repeated herein for the Examiner's convenience, along with additional remarks.

As described above, Claims 1-4 and 158 are amended to clarify that the second metal is different from a metal in the adjoining under-bump layer, wherein the intermetallic compound is formed between the solder bump and the adjoining under-bump layer.

According to the present invention, a semiconductor device is characterized in that an alloy layer, of at least a main component of the alloy solder and a different component which is also different from a metal in the adjoining under-bump, or UBM, layer is formed between the solder and the adjoining UBM layer. Since part of the UBM layer may melt, the alloy layer may be made of an alloy of a main component of the solder, a component different from the UBM layer, and a component of the adjoining UBM layer.

Accordingly, when soldering, the above alloy layer is first formed between the solder and the adjoining UBM layer, and thereby diffusion reactions in the following steps are effectively suppressed.

Marlin discloses an alternative structure as shown in Fig. 5 or Fig. 6 such that, from the solder side, a solder (Pb-free), a Cu layer, a Ni layer, and a TiW layer are laminated. However, Marlin's Fig. 6 shows only an example that one of Cu, Au and Ni is included in the solder on a TiW layer, and it is unclear how the layer 304 of Fig. 5 has been processed.

Marlin does not teach or suggest the feature of the present invention such that the alloy layer of at least a main component (for example, Sn) of the alloy solder and a second metal different from the metal that is the main component of the alloy soldier, said second metal also being different from a metal in the adjoining under-bump layer (for example, an under-bump layer including Ni) where the alloy layer is formed between the solder and the adjoining UBM layer, and thereby diffusion reactions due to repeatedly applied heat processes are suppressed.

Marlin is directed to forming a solder on an optional support stud without wetting by forming the support stud of Cu on a non-wettable layer of TiW. Marlin discloses that "After heating and reflowing, the solder bump will envelop the support stud but will maintain the proper shape for use in bonding because of the presence of non-wettable layer." (See col. 3, lines 8-12 and Fig. 6). It is also clear from Fig. 6 that the Cu support stud (308) is enveloped by the solder bump (310) without forming an intermetallic compound of the present invention.

Thus, the Examiner cites the primary reference Marlin as apparently disclosing a UBL comprising an electrically conductive nonwettable material such as titanium (Ti) or titanium-tungsten (TiW) alloy (**element 302** in Fig. 5; col. 2, lines 15-30) (see Office Action, page 3, lines 12-14). However, Applicants kindly point out that in Marlin's Figure 6, if element 302 is the UBL, then there is no intermetallic compound formed between the solder bump and the adjoining UBL, as required by the present invention.

In Chan et al., as illustrated for example in Fig. 2, from the solder side, a solder (PbSn which is Pb-rich), a solder reactive metal layer (Cu), a phased metal layer (CrCu), a barrier layer (Cr), a stress release layer (Cu), and an adhesive layer (Cr) are laminated. Applicants emphasize that the phased layer (CrCu) (element 44) represents the UBM layer from which to determine whether or not the second metal such as Cu is different than the main component of the alloy solder *and also different from the metal of the adjoining UBL.* When the solder melts, the Sn of solder is reacted with the Cu reactive layer, or Sn of the solder is reacted with Cu of the CrCu phased metal layer. When the solder is reacted with the Cu layer, Sn of the solder reacts with Cu to produce a CuSn-alloy layer. As a result, Cu of the CuSn alloy includes Cu of the CrCu layer

because Cr does not react. Since Cr has low wettability, Cr does not react with any of Sn, Cu and Pb. Accordingly, the CrCu layer is not an alloy but a CrCu-mixed layer.

Although the CrCu phased metal layer of Chan can avoid diffusion, Chan still does not teach or suggest the feature of the present invention that the alloy layer of at least a main component of the alloy solder and a component different which is also different from a metal in the adjacent UBM layer is provided between the solder and the adjacent UBM layer, and thereby diffusion is prevented. That is, Chan provides for a CuSn alloy layer where Sn is from the alloy solder, but where Cu is a component of the CrCu phased metal layer, or UBM layer, and does not satisfy the requirement of the present claims to include a second metal being different from a metal in the adjacent under-bump layer.

Even if the Examiner's understanding is that Chan teaches a *UBL containing Ti or W* (see Fig. 2, element 32) (see Office Action, page 4, first full paragraph), Applicants kindly point out that Chan would still fail to disclose or teach at least that the intermetallic compound (element 42) is located between the solder bump (element 38) and the adjoining UBL. That is, Chan's intermetallic compound (element 42) is between the solder bump and the adjoining phased metal layer (element 44 made of CrCu), but does not adjoin the UBL containing Ti or W (barrier layer-element 32). Chan teaches that a phased metal layer of CrCu comes between the intermetallic compound and the UBL containing Ti or W.

In Darveaux et al (USP 6,201,305), a solder bump is formed on wiring (Cu or Al) by selecting one of Cu, Au, Ni and the like as a pad. However, Darveaux et al is silent on bonding

conditions after melting. Accordingly, as in the case of Marlin, it is considered that diffusion reactions proceed due to repeatedly applied heat processes.

As described above, none of the cited references teaches an alloy layer of the present invention provided between a solder and an adjoining UBM layer, of at least a main component of the alloy solder and a second metal different from the metal that is the main component of the alloy soldier, said second metal also being different from a metal in the adjoining under-bump layer. When soldering, the above alloy layer is first formed between the solder and the adjoining UBM layer, and thereby diffusion reactions in the following steps are effectively suppressed.

It is considered that diffusion proceeds by substitution of metal atoms and grain boundary motion. As for both Cu and Ni, a similar reaction occurs. However, when an intermetallic compound has been formed for one, the other blocks the intermetallic compound to cut diffusion paths. Therefore, when the CuSn, for example, is initially formed at their interface, the Ni diffusion is suppressed.

In other words, according to the present invention, the solder and Cu for example, or the solder, Cu and Ni for example react to produce an alloy layer, and thereby diffusion reactions due to repeatedly applied heat processes can be suppressed.

Applicants kindly submit that the Examiner is improperly applying hindsight reconstruction by picking and choosing certain features from Marlin, Chan and Darveaux to apply against each and every element of the present invention which omits or ignores other features of the references which would teach against the present invention. However, for the

foregoing reasons, the combination of these references still fails to disclose, suggest or even teach each and every requirement of Applicants' claims.

Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejections under 35 U.S.C. § 103(a) in view of Marlin, Chan, and further in view of Darveaux.

C. Claims 13, 15, 17, 19, 49, 50, 53 and 54 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin and Chan et al as applied to claims 1, 5 and 9 above, and further in view of Andricacos et al (US Pat. 6,224,690) for the reasons given in the Office Action.

Regarding claims 49, 50, 53 and 54, the Examiner states that Andricacos et al. teaches using conventional adhesion/contact/barrier layers such as TiW between the wiring layer and the UBL.

D. Claims 14, 18, 51, 52, 55 and 56 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin, Chan et al and Darveaux et al as applied to claims 2, 6 and 10 above, and further in view of Andricacos et al for the reasons given in the Office Action.

Regarding claims 51, 52, 55 and 56, the Examiner states that Andricacos et al. teaches using conventional adhesion/contact/barrier layers such as TiW between the wiring layer and the UBL.

E. Claims 16 and 20 are rejected under 35 U.S.C. 103(a) as assertedly being unpatentable over Marlin, Chan et al and Darveaux et al as applied to claims 4, 8 and 12 above, and further in view of Andricacos et al for the reasons given in the Office Action.

Applicants respond as follows.

Based on the amendment to the independent claims and the remarks presented above in the obviousness rejections over Marlin in view of Chan, and further in view of Darveaux, Applicants submit that neither Darveaux or Andricacos or their combinations fail to overcome the previously cited deficiencies.

Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejections under 35 U.S.C. § 103(a).

New Claims

Applicants add new Claims 163-170 to cover additional embodiments disclosed in the specification. Although an important feature of the present invention relates to a two-element base compound layer which exists between a solder and an under-bump layer, other embodiments relate to an intermetallic compound of at least two metals provided between the solder and the under-bump layer.

In Claim 1, the two-element base compound layer includes metals A and B. Metal A is a metal which is the main component of the solder; and metal B is a metal which is different from the under-bump layer and is also different from the main component (A) of the solder. The two-element base compound layer is arranged to cut diffusion growth of an alloy formed of the metal

of the under-bump layer and the main component A of the solder, resulting in efficiently suppressed diffusion reactions.

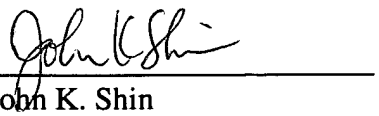
Assuming that the main component A of the solder is Sn, the metal of the under-bump layer is Ni, and the metal B is Cu, a semiconductor device according to Claim 1 has a Cu-Sn alloy layer provided between the solder and the under-bump layer. The Cu-Sn alloy layer stops diffusion growth of the Ni-Sn alloy. However, a little diffusion growth of the Ni-Sn alloy may initially occur, resulting in the Ni-Sn alloy and the Cu-Sn alloy compounded (see page 17, lines 3-5 of the description). Thus, the compounded presence of the Ni-Sn alloy and the Cu-Sn alloy is considered by adding new Claims 163-170 to cover these combinations. In other words, according to the above example, a claim directed to an alloy of Sn and Ni, for example, is added. Thus, entry and consideration of the new claims are respectfully requested.

Conclusion

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

The USPTO is directed and authorized to charge all required fees, except for the Issue Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any overpayments to said Deposit Account.

Respectfully submitted,



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